TEST BORING RECORD

ELEV. FT	DEPTH FEET	DESCRIPTION	FORMATION			PENETRATION-BLOWS PER FOOT (0 5 10 15 20 30 40 60 80 100)
379.0		TOPSOIL- VERY STIFF BROWN GRAY SILTY CLAY WITH ORGANICS AND LIMESTONE FRAGMENTS	PONCE			
	1.5	VERY HARD WHITE, TAN, GRAY SILTY CLAY WITH LIMESTONE FRAGMENTS AND SEAMS	JUANA DIAZ			
374.0						11
369.0						75
	11	WHITE TO GRAY LIMESTONE WELL CEMENTED, MODERATELY WELL JOINTED, CLAY COVERING SURFACE OF JOINTS		CORE NX	REC 0.6'	
					REC 2.0'	
364.0					REC 2.0'	
	16	WHITE TO GRAY LIMESTONE WELL CEMENTED CONTAINS CALCITE LINED CRACKS, SOME IRON STAINING			REC 4.0'	
359.0	20	VERY HARD TAN FINE SANDY SILTY CLAY, LIMESTONE SEAMS AND FRAGMENTS				75
354.0						7
349.0						7
344.0						7
339.0	40					

REMARKS:
COORDINATES
N: 19,338.39 M
E: 128,164.71 M

Drilled with Air Between Depths of 0 to 60'
Drilled with Water Between Depths of 60' to 127.5'
Boring grouted to Surface upon completion.

DRILLED BY Metropolitan SMT
LOGGED BY MJC
CHECKED BY LDW

BORING NUMBER C-90
DATE STARTED 3/13/84
DATE COMPLETED 3/19/84
JOB NUMBER GS-3223.55

TEST BORING RECORD

ELEV FT	DEPTH FEET	DESCRIPTION	FORMATION			PENETRATION-BLOWS PER FOOT
339.0	40	WHITE TO GRAY FINE SANDY SILTY LIMESTONE, MODERATELY WELL JOINTED, IRON STAINING, SOME CLAY LINING ON JOINT SURFACES	JUANA DIAZ	CORE NX	REC 0.5'	
					REC 1.9'	
334.0					REC 1.9'	
					REC 1.5'	
329.0	50	VERY HARD TAN TO WHITE FINE SANDY SILTY CLAY, POORLY CEMENTED				75/6
324.0						75/6
319.0	60	GRAY TO TAN FINE SANDY SILTY CLAYEY LIMESTONE, MODERATELY WELL-JOINTED WITH OCCASIONAL CLAY SEAMS AND IRON STAINING		CORE NX	REC 2.3'	
314.0					REC 2.0'	
					REC 1.8'	
309.0				CORE NX		
					REC 2.3'	
304.0						
299.0	80					

REMARKS:

DRILLED BY Metropolitan SMT
LOGGED BY MJC
CHECKED BY LDW

BORING NUMBER C-90
DATE STARTED 3/13/84
DATE COMPLETED 3/19/84
JOB NUMBER GS-3223.55

TEST BORING RECORD

ELEV. FT	DEPTH FEET	DESCRIPTION	FORMATION		PENETRATION-BLOWS PER FOOT 0 5 10 15 20 30 40 60 80 100
299.0	80		JUANA DIAZ		
294.0		GRAY TO TAN FINE SANDY SILTY CLAYEY LIMESTONE, MODERATELY WELL JOINTED, WITH OCCASIONALLY CLAY SEAMS AND IRON STAINING		REC 1.5'	
289.0					
284.0					
279.0	99	TAN FINE SANDY SILTY LIMESTONE, MODERATELY WELL JOINTED HORIZONTALLY @ 45°, MODERATELY WELL CEMENTED, SOME CALCITE LINED JOINT SURFACES		REC 2.2'	
274.0					
269.0				REC 1.4'	
264.0					
259.0	120				

REMARKS:

DRILLED BY Metropolitan SMT
LOGGED BY MJW
CHECKED BY LDW

BORING NUMBER C-90
DATE STARTED 3/13/84
DATE COMPLETED 3/19/84
JOB NUMBER GS-3223.55

TEST BORING RECORD

ELEV. FT	DEPTH FEET	DESCRIPTION	FORMATION			PENETRATION-BLOWS PER FOOT 0 5 10 15 20 30 40 60 80 100
259.0	120	TAN FINE SANDY SILTY LIMESTONE MODERATELY WELL JOINTED HORIZONTALLY @ 45°, MODERATELY WELL CEMENTED, SOME CALCITE LINED JOINT SURFACES	JUANA DIAZ			
254.0	125	GRAY CLAYEY LIMESTONE WITH VERTICAL JOINTS			REC 1.9'	
	127.5					
249.0		BORING TERMINATED @ 127.5 feet				

REMARKS:

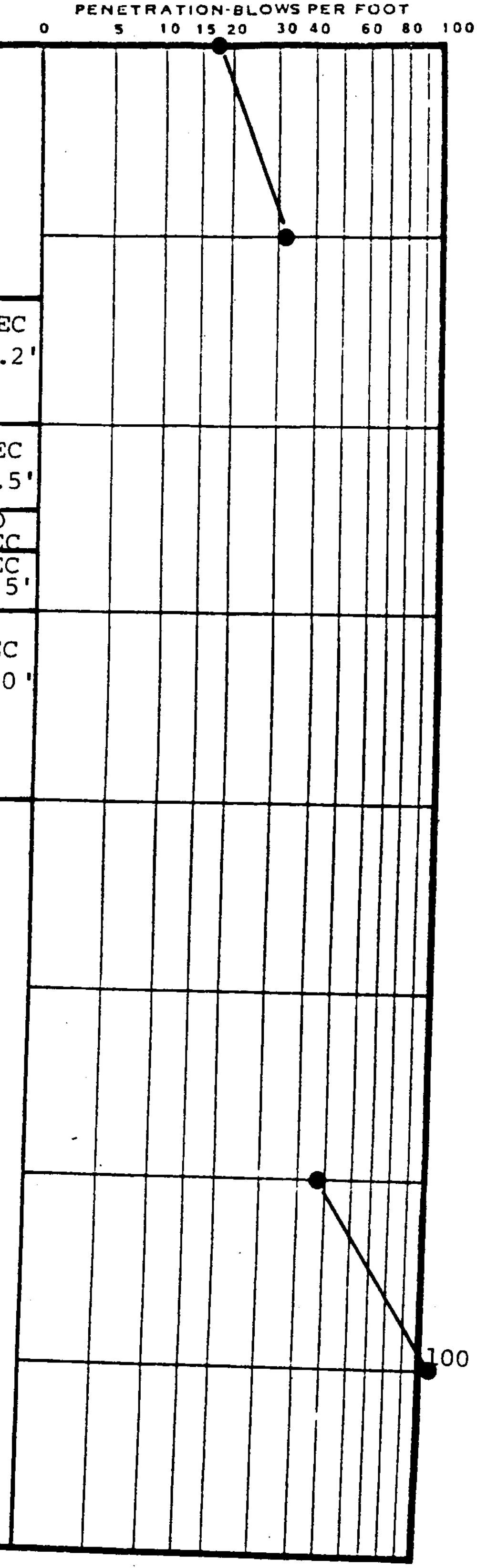
DRILLED BY Metropolitan SMT
LOGGED BY MJC
CHECKED BY LDW

BORING NUMBER C-90
DATE STARTED 3/13/84
DATE COMPLETED 3/19/84
JOB NUMBER GS-3223.55

TEST BORING RECORD

ELEV FT	DEPTH FEET	DESCRIPTION	FORMATION		
434.7		VERY STIFF TO HARD LIGHT GRAY, TAN FINE SANDY SILT; WEAKLY CEMENTED (SURFACE DISTURBED BY ACCESS CONSTRUCTION)	PONCE		
429.7					
	6.6	VERY HARD TAN LIMESTONE JOINTING @ 45°	JUANA DIAZ	CORE NX	REC 3.2'
424.7	10	TAN LIMESTONE, HIGHLY FRACTURED, NEAR HORIZONTAL JOINTS			REC 0.5'
					NO REC
					REC 1.5'
419.7					REC 3.0'
414.7	20	VERY HARD FINE SANDY SILT, CEMENTED LIMESTONE AND CALCITE SEAMS			
409.7					
404.7					
399.7					
394.7	40				

PENETRATION-BLOWS PER FOOT



REMARKS:
Coordinates:
N: 19,432.02m
E: 128,111.98m
Drilled with air between depths 0 to 115'
Drilled with water between depths 115 to 158'
Boring grouted to surface upon completion

DRILLED BY Caribbean ST
LOGGED BY MJC
CHECKED BY LDW

BORING NUMBER C-91
DATE STARTED 3/13/84
DATE COMPLETED 3/16/84
JOB NUMBER GS-3223.55

TEST BORING RECORD

ELEV FT	DEPTH FEET	DESCRIPTION	FORMATION			PENETRATION-BLOWS PER FOOT
394.7	40	WHITE FINE SANDY SILTY LIMESTONE MODERATELY WELL JOINTED, CLAY COVERING ON SOME JOINT SURFACES, SOME IRON STAINING	JUANA DIAZ	CORE NX	REC 2.0'	
					REC 1.9'	
389.7					REC 4.3'	
384.7	50	VERY HARD TAN, GRAY FINE SANDY SILTY CLAY, POORLY CEMENTED, LIMESTONE SEAMS & FRAGMENTS				
379.7						100/
374.7						100/
369.7						100/
364.7						100/
359.7						100/
354.7	80					

REMARKS:

DRILLED BY Caribbean ST
LOGGED BY MJC
CHECKED BY LDW

BORING NUMBER C-91
DATE STARTED 3/13/84
DATE COMPLETED 3/16/84
JOB NUMBER GS-3223.55

TEST BORING RECORD

ELEV. FT	DEPTH FEET	DESCRIPTION	FORMATION			PENETRATION-BLOWS PER FOOT
354.7	80	GRAY, TAN FINE SANDY SILTY LIMESTONE WELL CEMENTED MODERATELY WELL JOINTED HORIZONTALLY	JUANA DIAZ	CORE NX	REC 5.0'	
349.7					REC 5.0'	
344.7	90	VERY HARD GRAY TO GREEN FINE SANDY SILTY CLAY, WITH LIMESTONE FRAGMENTS				75
339.7						100
334.7	100	TAN LIMESTONE POSSIBLY HIGHLY FRACTURED		CORE NX	NO REC	
329.7						
324.7	110	VERY HARD GRAY TO GREEN FINE SANDY SILTY CLAY		CORE NX	REC 4.2'	
319.7	114.2	GRAY TO TAN FINE SANDY SILTY LIMESTONE WELL CEMENTED WITH SOME IRON STAINING			REC 1.2'	
314.7	120					

REMARKS:

DRILLED BY Caribbean ST
LOGGED BY MJC
CHECKED BY LDW

BORING NUMBER C-91
DATE STARTED 3/13/84
DATE COMPLETED 3/16/84
JOB NUMBER GS-3223.55

APPENDIX 6

Report of Geotechnical Data From Borings C-88,
C-89, C-90, C-91
Ponce Waste Facility
Ponce, Puerto Rico

F - SUMMARY DESCRIPTION OF CONTAMINANT TRANSPORT MODEL

SUMMARY DESCRIPTION OF CONTAMINANT TRANSPORT MODEL
(Abstracted From Konikow and Bredehoeft)

The model calculates the transient changes in the concentration of a nonreactive solute in flowing ground water. The computer program solves two simultaneous partial differential equations. One equation is the ground-water flow equation, which describes the head distribution in the aquifer. The second is the solute-transport equation, which describes the chemical concentration in the system. By coupling the flow equation with the solute-transport equation, the model can be applied to both steady-state and transient flow problems.

The purpose of the simulation model is to compute the concentration of a dissolved chemical species in an aquifer at any specified place and time.

The equation describing the transient two-dimential areal flow of a homogeneous compressible fluid through a nonhomogeneous anisotropic aquifer can be written in Cartesian tensor notation as

$$\frac{\partial}{\partial x_i}\left(T_{ij}\frac{\partial h}{\partial x_j}\right)=S\frac{\partial h}{\partial t} + W \qquad i,j = 1,2 \qquad (1)$$

Where

T_{ij}	is the transmissivity tensor, L^2/T;
h	is the hydraulic head, L;
S	is the storage coefficient, (dimensionless);
t	is the time, T;
$W=W(x,y,t)$	is the volume flux per unit area (positive sign for outflow and negative for inflow), L/T; and
x_i and x_j	are the Cartesian coordinates, L.

The equation used to describe the two-dimensional areal transport and dispersion of a given nonreactive dissolved chemical species in flowing ground water may be written as

$$\frac{\partial (Cb)}{\partial t} = \frac{\partial}{\partial x_i}\left(bD_{ij}\frac{\partial C}{\partial x_j}\right) - \frac{\partial}{\partial x_i}(bCV_i) - \frac{C'W}{\varepsilon} \qquad i,j = 1,2 \quad (2)$$

where

C	is the concentration of the dissolved chemical species, M/L^3
D_{ij}	is the coefficient of hydrodynamic dispersion (a second-order tensor), L^2/T;
b	is the saturated thickness of the aquifer, L; and
C'	is the concentration of the dissolved chemical in a source or sink fluid M/L^3

Because aquifers have variable properties and complex boundary conditions, exact analytical solutions to the partial differential equations of flow (eq 1) and solute transport (eq 2) cannot be obtained directly. Therefore, approximate numerical methods must be employed.

The numerical methods require that the area of interest be subdivided by a grid into a number of smaller subareas. The model described herein utilizes a rectangular, uniformly spaced, block-centered, finite-difference grid, in which nodes are defined at the centers of the rectangular cells.

The accuracy of the numerical solution to the solute-transport equation has been evaluated by comparison of the numerical solution with available analytical solutions. One such comparison is shown in Figure A1 which depicts the concentration distribution for the problem of steady state radial flow through a homogeneous, isotropic porous medium in which a well continously injects a tracer with concentration C_0. This represents a severe test of the model. Nevertheless, as demonstrated by Figure A1, there is good agreement between the analytical and numerical solutions at two different times.

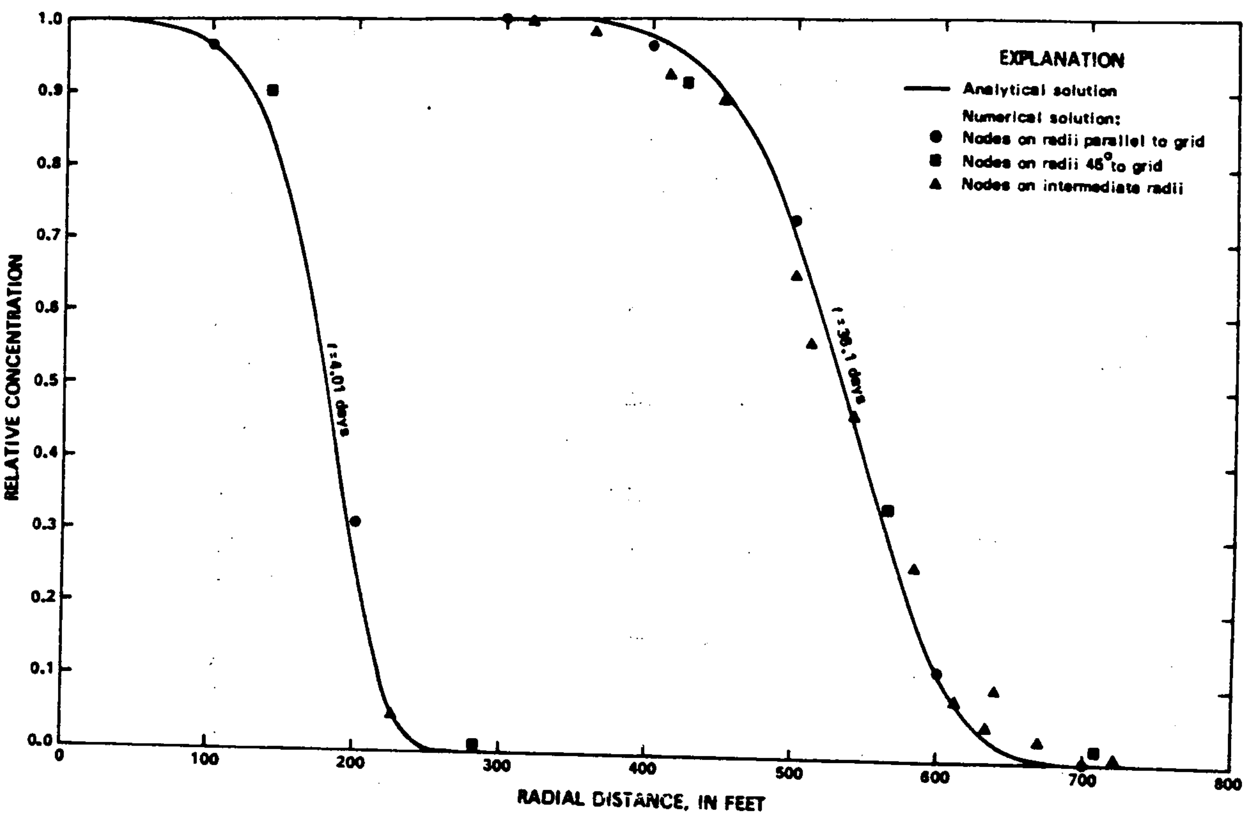


Figure A1 -Comparison between analytical and numerical solutions for dispersion in plane radial steady-state flow.

Figure 3 shows the geology of the site as interpreted from the following data;

- o 81 (approx.) test borings ranging in depth up to 400 feet.
- o 5300 feet of seismic refraction surveys.
- o 5600 feet of electromagnetic surveys
- o 3330 feet of downhole geophysical logging.
- o detailed geologic mapping.
- o an exhaustive literature review and personal communications with the U.S. Geological Survey and geologists familiar with the area.

Figure 3 is included to show the spatial relationshp between geologic and hydrogeologic features and the locations of boreholes and other site data collection activities.

Residual materials encountered in the borings for the Phase II monitoring wells (MW-6, MW-7 and MW-8) consisted of silty clays and clayey silts of the Juana Diaz formation. These materials were indistinguishable from materials in exploratory borings penetrating the Juana Diaz formation drilled during the site characterization phase and during Phase I of the hydrogeologic assessment. Five of six samples tested from this formation contained greater than 70 percent fines (material passing a 0.074mm sieve opening). (See grain size curves in Appendix.) A significant percentage of clay minerals is indicated by the grain size distributions, which show greater than 25 percent clay-sized particles in four of six samples tested, and by the medium to high plasticity of the soils (liquid limits ranging from 38 to 93; plasticity indices ranging from 16 to 54).

Data available at this time indicate that the main west-northwesterly trending faults act as hydrogeologic barrier separating ground water in the Juana Diaz formation south of the faults from the ground water in the Ponce formation north of fault. Another fault, which occurs on the south side of the site also acts as a hydraulic barrier which separates ground water in the Juana Diaz formation from the Ponce. Additonal water level, water chemistry and geologic data obtained during and following installation of the monitoring wells indicate the presence of several fault blocks within the Juana Diaz formation. These fault blocks, plus the steeply dipping beds and impermeable unsaturated zone, are controlling the occurrence and movement of ground water within the Juana Diaz formation and in the cell area.

1.2.2.2 Potentiometric Levels

During drilling, the depth at which ground water is first encountered cannot always be determined exactly. It depends, to some extent, upon the drilling method being used. In air-rotary drilling the first encounter with water may be either abrupt or gradual. If the drill penetrates a hard confining layer and abruptly breaks into a saturated zone, the cuttings and soil cores from the hole will suddenly be saturated. In this case the location of the saturated zones can be determined with a high degree of certainty. In other cases there may be a capillary zone or a perched zone at some distance above the aquifer. In this situation the first encounter with the aquifer cannot be determined exactly because either the change in moisture content is gradual or, in those cases where the moist cuttings cannot be removed from the hole by air lifting, it is necessary to use water as the drilling fluid. Once drilling water fills the hole, it is much more difficult to determine where ground water is encountered.

Water levels in monitoring wells drilled in the Juana Diaz formation were found at varying elevations irrespective of depth of the hole. These data along with geologic and water chemistry information indicate that known fault blocks within the Juana Diaz formation may not be hydraulically interconnected. This would imply that ground water occurs in tightly trapped pockets within the faulted Juana Diaz and that each of these pockets is independent of both a regional aquifer system and other fault blocks. The following is a discussion of water level variations encountered during drilling of the monitoring wells.

The potentiometric levels in some of the monitoring wells are above the level where water was first encountered in the boring, indicating confined or artesian conditions. This was clearly the case in three of the monitoring wells. As shown on Table 2, an increase in the ground water elevation of about 8.5 feet occurred in MW-3 after the first encounter with water was made at elevation 172.8 feet msl. Larger rises were noted in MW-7 and MW-8 where the increases in ground-water levels were about 37 and 139 feet, respectively.

Moist soil was encountered at an elevation of 153.7 in MW-1. The hole was then drilled about 30 feet deeper and bailed. After bailing, water reentered the hole and the assumption was made that a saturated zone had been encountered. Subsequently, the water level in MW-1 declined until eventually the hole became dry. MW-1 was then replaced by MW-6. Moist soil was encountered in MW-6 at an elevation of approximately 72 feet msl. This hole was then extended to an elevation of 15 feet msl using water for drilling. Periodic bailing was conducted to check for the presence of ground water. A stable water level in MW-6 was determined to be about 46 feet msl. In drilling both MW-1 and MW-6, circulation of the drilling water was lost, indicating that some portions of the formation were absorbing this fluid.

In drilling MW-2, air was used until a saturated sample was recovered. The breakthrough into the saturated zone was abrupt, and the location of this zone was easily determined. The same was true for MW-3 and MW-7.

However, in MW-2 two different water-bearing zones in the Juana Diaz formation were encountered during drilling of MW-2. While advancing the borehole using air-rotary methods, greenish gray clayey silt cuttings were noted at a depth of 23 feet. When the drill rods and split spoon were retrieved after sampling at a depth of 29 feet, the last several feet of rods and the split spoon were dripping wet. Drilling was suspended and water levels recorded in the open borehole. In thirty minutes the water rose 2.4 feet in the borehole indicating a minimum expected head of 26.6 feet below ground surface. The borehole was then advanced using wash-rotary methods to 60 feet. (The procedure used for the construction of the monitoring wells was to drill to a depth of 30 feet below the elevation of the water table.) At 32 feet below ground surface, a strata change occurred from direction. If a leak occurred directly into a fault, the contaminant would move away from the fault toward the monitoring wells.

On the other hand, if the fault provided a continuous high permeability path in the direction of the fault, the fault might tend to act as a drain rather than a recharge zone, and the ground water levels near the fault would be lower than that in the surrounding rock. This is not the case at Cell Number 1 where the highest potentiometric values are those nearest the fault that crosses Cell Number 1, i.e., at MW-2, MW-3 and MW-7.

Evidence is stronger that the faults are acting as barriers to ground water flow. The "fault as a barrier" was discussed in the SCR. Data obtained early in the study of the Ponce site and reported in the SCR showed the main fault crossing the site and separating the Ponce from the Juana Diaz to act as a barrier to ground water flow. This evidence has been strengthened by data subsequently obtained from MW-8. MW-8 has a water level of about 150 feet MSL. It is only about 200 feet south of the fault. On the north side of the fault, in the Ponce formation, water level in C-15 was 15 feet MSL. If the fault were not acting as a barrier, the ground water in the Juana Diaz would flow into and come into equilibrium with the ground water in the Ponce formation. The evidence shows that this has not happened.

MW-3, MW-4 and MW-1 due to the breakdown of the steam cleaning rig. Prior to drilling MW-2 and completion of drilling at MW-5 (48 to 64 feet) the drill rig and equipment were mobilized to a nearby fire station. At the fire station tools and equipment were placed on sawhorses and the rig and equipment thoroughly cleaned using potable water under very high pressure flowing through a fire hose connected to a fire hydrant.

Permeability Testing

Field permeability tests were performed in six of the eight wells installed at the test boring locations. These permeability tests or "slug" tests were performed by raising or lowering the water level in the well with a weighted float (slug in) or bailer (slug out) and subsequently measuring the gradual water level decline or rise with an electric tape. In the case of "slug in", once the water level reached static conditions the float was removed from the well (slug out) and the recovering water level was measured.

Water level information was plotted on semilog graph paper on the linear axis against time in seconds on the log axis (Lohman, 1979). A family of matching curves were overlain on the data plot so that the plotted data points best fit one of the type curves. A value of time (t) in seconds on the data plot was picked where the data coordinate was found to overlie the value of $Tt/rc^2 = 1.0$ on the type curve. Once the value of t (seconds) was obtained it was used in the equation: